DOCUMENT RESUME

ED 059 681 HE 002 847

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TITLE Enrollment Projection Models for Institutional Planning.
INSTITUTION American Coll. Testing Program, Iowa City, Iowa. Research and Development Div.
REPORT NO Act-RR-48
PUB DATE Jan 72
NOTE 13p.
AVAILABLE FROM Research and Development Division, The American College Testing Program, P. O. Box 168, Iowa City, Iowa 52240 ($1.00)

EDRS PRICE MF-$0.65 HC-$3.29
DESCRIPTORS *Educational Demand; *Educational Planning; *Enrollment Projections; Enrollment Rate; *Enrollment Trends; *Higher Education; Institutional Administration; Planning

ABSTRACT

This paper examines alternative techniques for projecting freshman enrollment in specific academic departments. Departmental enrollment projections provided by 4 different projection models are compared to actual departmental enrollments at Kansas State University. Two of the models use only historical data, while the other two models are sensitized to current developments as indicated by the expressed major choices of prospective freshmen. The use of discriminant analysis to establish differential enrollment probabilities is also explored. Although different models do a better job for different curricular departments, the smallest mean squared across all departments was obtained with the simplest projection technique. Based on the results obtained at this one institution, therefore, it would appear that simple and straightforward projection models can be useful as complex and sophisticated models. (Author/HS)

ACT RESEARCH REPORT

No. 48

48

January, 1972

ED 059681

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PUBLISHED BY THE RESEARCH AND DEVELOPMENT DIVISION
THE AMERICAN COLLEGE TESTING PROGRAM
P. O. BOX 168, IOWA CITY, IOWA 52240

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Although different models do a better job for different curricular departments, the smallest mean squared error across all departments was obtained with the simplest projection technique. The use of the preliminary major choice of prospective freshmen did not improve departmental projections, and the student characteristics explored in this study did not differentiate enrolled from nonenrolled students adequately enough to improve enrollment projection accuracy.

Based on the results obtained at this one institution, therefore, it would appear that simple and straightforward projection models can be as useful as complex and sophisticated models.

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ENROLLMENT PROJECTION MODELS FOR INSTITUTIONAL PLANNING[1]

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Enrollment projection models derive from the earliest budgetary processes used at colleges and universities. Implicitly, if not explicitly, the development of a budget involves some estimate of enrollment during the budgetary year. Typically the projection models were designed to estimate an institution's total enrollment (see, e.g., Hoyt & Munday, 1968, pp. 119-122); and for many years this estimate was considered adequate for the planning and budgetary cycles. More recently, however, with the application of the Planning, Programming, and Budgeting System (PPBS) to higher education, with the development of simulation models, and with the recognition of cost differentials associated with different programs offered within the institution, more detailed enrollment projections are required. In addition, as planning is decentralized to lower-level units such as schools or academic departments, decentralized enrollment projections are necessary to determine faculty loads, staffing requirements, space allocations, etc.

This paper, therefore, examines alternative enrollment projection models designed to predict enrollment in specific institutional categories or departments. Because enrollments in specific departments vary from year to year and because the proportional variation in departments may be greater and in a different direction than the variation in total institutional enrollment, the results of departmental projections at a selected institution are compared with two models using only historical data and with two models sensitized to current developments as indicated by the expressed major choices of prospective freshmen.

Wasik (1971) classified enrollment projection models into three categories: (a) extrapolation models that use cohort data to develop straightline extrapolations or linear regression equations to estimate enrollment, (b) structural flow models that use differential equations to estimate the flow of individuals through the system, and (c) Markov chain models that use a transition matrix to estimate the movement of students through or between different departments. In this paper we explain and test two simple extrapolation models, a structural flow model based on current information of the expressed major choices of prospective freshmen, and a Markov transition model that combines current information on major choice with the probability of enrollment in other departments.

[1]This is an updated and expanded version of an earlier paper, "Projecting Freshman Enrollment in Specific Academic Departments," read at the 1971 Association of Institutional Research Forum in Denver, Colorado.

Procedure

Since pre-enrollment data routinely collected by The American College Testing Program (ACT) were used as the projection data and since the results of the projections were compared to actual enrollment, it was important to pick a college where freshmen typically select a major and where incoming students are required to take the ACT Assessment Battery. Kansas State University (KSU) satisfied these requirements and was selected after officials there expressed a desire to participate in such a study.[2]

The ACT Class Profile Service maintains files for this institution for both enrolled and nonenrolled students. The major areas on the ACT Assessment Battery were classified according to KSU departments, and the ACT information was then merged with the KSU information. Actual freshman figures by department were obtained for a 5-year period, beginning in the fall of 1965. Using these two data sets where appropriate, enrollments were projected for entering freshmen in the fall of 1969 using the models described below.

Baseline Model

The baseline model assumes that changes in enrollment occur only as a function of overall institutional growth, i.e., that the ratio of departmental enrollment to total enrollment is constant across time for each department.

The model is probabilistic in nature and does not yield an estimate of total enrollment. It requires, therefore, a projection of total enrollment from some other source or estimate in order to project departmental enrollment. Thus, the ratio of departmental enrollment to total enrollment in 1968 times the projected total enrollment for 1969—this latter figure obtained from regression analysis of total enrollment at KSU in the previous 4 years—provides the projected enrollment for each department in 1969.

Trend Line Model

In the trend line model, prediction is based on regression analysis of the trends in department enrollment figures over a period of years. If the enrollment in a department has stabilized, there will be no projected change in enrollment for the coming year in that department. If enrollment has steadily increased or decreased, the projection will be based on a continuation of the trend. No provision is made in this model to adjust for abrupt changes that may occur in an individual department.

Thus, projected enrollment in each department ($\hat{Y}$) is the linear regression of actual enrollment in each KSU departmental grouping for 1965, 1966, 1967, and 1968 in the form $\hat{Y} = bX + c$. Total projected enrollment for KSU is found by summing the projected enrollment for each individual department.

Simple Ratio Model

Because research has indicated that students tend to major in the area they chose prior to college entrance,[3] the simple ratio model incorporates recent information on the intended major of freshmen planning to attend KSU. Through this procedure it was anticipated that this model would be sensitized to abrupt changes in departmental enrollment trends, thus providing an early warning signal to college administrators regarding the necessity for reallocation of staff, equipment, and facility requirements.

This model used the educational major choice that the prospective student indicated when taking the ACT Assessment during the year or two preceding enrollment. Thus, the ratio of the proportion of prospective students in 1968 expressing a particular choice of major to the proportion of students in 1969 expressing the same major is multiplied by the number of students who actually enrolled in 1968. If the number of students sending their ACT scores to the college and expressing a particular choice of major increases or decreases in comparison with the number expressing that choice of major the preceding year, the prediction will be that the number of enrolled students actually majoring in that area will increase or decrease proportionately over the present year.

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[2]The authors hereby express thanks to Kansas State University and especially to Donald P. Hoyt and Donald Tarrant of the Office of Educational Resources for their help in obtaining data from university files.

[3]In a study of students attending a national sample of colleges, Lutz (1968) found that slightly over half the students were in the same major field of study that they had chosen at the time they took the ACT Assessment. Of those who changed, a large proportion selected closely related fields.

Markov Model

The use of Markov models for certain kinds of population size estimation has been summarized by Wasik (1971). The basic idea is to allow for different rates of enrollment for various intended educational majors and subsequently to modify estimates according to the tendency of students to switch to other, possibly closely related, departments. The latter modification is accomplished by means of a transition matrix.

Each row of the transition matrix represents an existing state of the system (namely, intended educational major); the columns represent outcomes (the department in which the student actually enrolls). The entries in any row are proportions which total to unity, reflecting the fact that each student who enrolls must select some department. Both rates of enrollment and the transition matrix entries are established by historical data; these quantities are assumed to be relatively stable over time.

The number of students projected to enroll in a specific department, therefore, is a function of the proportion of students who indicated major X in the previous year and who actually enrolled at the college plus the proportion of enrolled students in the previous year who indicated other majors and who changed to major X, minus the proportion of enrolled students who were in major X in the previous year and who changed to other majors. Suppose, for example, that a particular institution consists of only two departments, A and B. Of 1,000 students who take the ACT Assessment, 500 indicate they will major in Department A and F00 indicate they will major in Department B. If the simple ratio model discussed above were used, we would simply compute the ratio of the proportional enrollment in Departments A and B in the previous year to the proportion indicating Departments A and B as their major this year and project enrollments in each department on the basis of these ratios.

Additional historical information is available, however, which the Markov model incorporates. Past experience, for example, may indicate that 60% of those who prefer Department A actually enroll in the university, whereas 80% of those who prefer Department B do so. Furthermore, past experience also indicates that all of the Department A candidates who enroll in the university will confirm their original intention to enroll in that department and 20% of Department B candidates will switch departments. In the Markov model we apply the enrollment probabilities in each department, and then using the transition matrix we modify these probabilities according to the tendency of students to switch departments by solving the basic Markov relation:

$$q_j = \sum_i a_i p_{ij}$$

Where

q_j = the adjusted departmental enrollment probability for the jth department in the projection year;

a_i = the proportion of total expected enrollment intending to major in the ith department;

p_{ij} = the proportion of enrollees in the previous year who intended to major in department i and actually majored in department j (i may or may not be equal to j).

The transition matrix for our two-department institution would appear as follows:

		Actual Department	
		A	B
Intended Department	A	p_{11} = 1.00	p_{12} = .00
	B	p_{21} = .20	p_{22} = .80

This matrix indicates that in the previous year all of the enrolled students who intended to major in Department A did so and none switched to Department B, whereas 20% of those who intended to major in Department B switched to Department A and the remaining 80% enrolled in Department B. Solving for q_j, projected enrollment for each department is determined as follows:

Department A = 700 (q_1) = 700 (.5428) = 380;

Department B = 700 (q_2) = 700 (.4571) = 320.

This result is, of course, intuitively obvious from the preceding matrix with projected enrollment in Department A equaling all of enrolled students intending to enroll in Department A plus 20% of those intending to enroll in Department B (300 + .20 (400) = 380) and projected enrollment in Department B equaling 80% of enrolled students intending to major in Department B (400 x .80 = 320). But as the number of departments increase,

the matrix increases in size, the interrelationships among departments become more complex, and the computational complexity is correspondingly increased.

An advantage of the Markov model is that it is sensitized to recurring enrollment patterns; but it dampens the effect of spurious choices of major that, based on historic information, do not represent stable, permanent choices. In the example cited, although a smaller proportion preferring Department A are expected to enroll at the university, this effect is attenuated by the fact that Department A candidates who enroll remain true to their choice.

Discriminant Analysis

The technique of discriminant analysis has enjoyed widespread application in the behavioral sciences; some important examples have been cited by Cooley and Lohnes (1971). Our current interest was to compute discriminant functions based upon student interests and abilities which maximize the separation between enrolled and nonenrolled students. This discriminant function would then provide an enrollment probability for each student. Thus, this approach could be used to improve either the simple ratio model or the Markov model by weighting each intended educational major by the probability of enrollment for that student.

Results

Although projected total enrollment for each model is provided in Table 1, the focus of our analysis is on the relative effectiveness of the models at the departmental level. It is possible, however, to compare the total enrollment projections of the trend line and simple ratio models. Table 1 indicates that both models understated total enrollment in 1969 with the trend line model projecting 2,854 students and the simple ratio projecting 2,914. The understatement of total enrollment by the trend line model becomes understandable when it is observed, in Table 2, that the total enrollment declined at KSU from 1965 through 1968. The regression estimates, therefore, project a continuing decline for 1969. The simple ratio model, on the other hand, is determined by the ratio of prospective departmental enrollees in 1968 and 1969 and, as a consequence, would not normally be expected to project an increase in total enrollment in 1969.

The baseline and Markov models are probabilistic in nature and by themselves do not provide a total enrollment figure. In the absence of other guidelines, we used the trend line projection of total enrollment for both the baseline and Markov models to project departmental enrollment. Although this may be the most frequently used method to project total university enrollment, it is simplistic and ignores other factors that could be included. Wasik (1971), for example, when discussing the use of a Markov model to project departmental enrollment in community colleges, recommends the development of a regression equation for projecting community college total enrollment based on the number of high school graduates, required local draft board needs, an estimate of economic activity, and the county population.

Because each model either used or provided a different total enrollment, it was necessary to define a common denominator that would enable comparison of the models on the basis of their projection of departmental enrollments which was the primary focus of this paper. This result was accomplished by comparing them on the basis of their predicted percentage distribution within each department as summarized in Table 1. This table compares the relative effectiveness of the various techniques. For each department the actual 1969 enrollment percentage and the percentage deviation of the projection from the actual percentage are given for each model. Summary statistics include mean squared error, mean absolute error, and the number of departments in which the more complex models performed better than the baseline model.

Results indicated that in the case of this particular institution, more complex projection models did not improve prediction. Using mean squared error as the primary criterion of effectiveness, we noted that the baseline model projected the smallest deviation from actual enrollment in 1969 followed by the trend line, the Markov models, and the simple ratio. The same general relationship obtained for the mean absolute error. The simple ratio approach yielded the worst results because the prediction was notably inaccurate in

TABLE 1

Relative Effectiveness of Each Model Expressed as Percentage Deviation from Percentage Actually Enrolled in 1969

Department	Percentage Actually Enrolled	Model				
		Baseline	*Trend Line*	*Simple Ratio*	*Markov (Sexes Combined)*	*Markov (Sexes Computed Separately)*
1. Agriculture	11.02%	.79%	.66%	1.57%	1.38%	1.49%
2. Architecture	4.70	1.07	.30	1.23	1.22	1.23
3. Traditional Liberal Arts	14.20	−2.29	−1.53	−2.67	−2.01	−1.76
4. Education	11.57	.72	−.02	−.18	.44	.58
5. Health-Related Fields	7.94	1.38	1.09	.43	.81	.57
6. Other Preprofessional Fields	3.18	−.72	−1.00	−.60	−.60	−.64
7. Undecided or General	17.34	.93	2.89	5.82	1.84	1.53
8. Business	7.97	−.80	−.97	−.46	−.35	−.47
9. Engineering	10.86	.13	−.64	−.64	.14	−.16
10. Home Economics	11.22	−1.21	−.75	−4.39	−2.87	−2.32
Total Projected Enrollment	3,085[a]	2,854	2,854	2,914	2,854	2,854
Mean Squared Error[b]		1.29%	1.53%	6.54%	2.04%	1.59%
Mean Absolute Error[b]		1.00%	.99%	1.80%	1.16%	1.08%
Number of departments in which more complex technique was better than baseline		——	6	4	5	5

[a]Actual enrollment in 1969.

[b]Mean squared error is the average of the squared differences between the projected enrollment percentage and the actual enrollment in each department. Mean absolute error is the average of the differences taken without regard to sign. Thus, mean squared error tends to accentuate the seriousness of the largest discrepancies.

certain categories, particularly in the undecided and home economics categories.

Indeed, it was the undecided category that offered a good contrast of the relative merits of the simple ratio and Markov models. It was not surprising that a relatively high proportion of prospective students would be undecided about their major when taking the ACT Assessment before enrolling. In Table 2 we note that the number of students in this category was the same for 1968 and 1969, indicating that approximately the same proportion of prospective students were undecided about their major during both of these years. The simple ratio projection reflected this fact; but the Markov model, on the other hand, allowed for adjustment in this unstable major choice by providing a mechanism (the transition matrix) to allow for flow from and to this category as a reflection of later decisions made by students. Consequently, the projection of this category by the Markov model was much more accurate than that provided by the simple ratio model.

In all but two departments both Markov models were better than the simple ratio model, but trend line projections were better than the Markov projections in five departments. It should be noted further that even though the baseline model had the smallest mean squared error, the projections of the trend line model were better in six departments, and the Markov projections were better than the baseline in five departments. A final reference to Table 1 indicates that further refine-

TABLE 2

Actual Enrollment by Department at Kansas State University, 1965-1969[a]

Department	Year				
	1965-66	*1966-67*	*1967-68*	*1968-69*	*1969-70*
1. Agriculture .	330	314	306	345	340
2. Architecture	200	157	148	169	145
3. Traditional Liberal Arts	277	297	302	349	438
4. Education	409	338	350	360	357
5. Health-Related Fields	349	282	319	273	245
6. Other Preprofessional Fields	67	97	47	72	98
7. Undecided or General	503	530	590	535	535
8. Business	220	229	199	210	246
9. Engineering	436	375	366	322	335
10. Home Economics	313	371	325	293	346
Total	3,104	2,990	2,952	2,928	3,085

[a]The departmental classification is that of the authors although it closely approximates the undergraduate colleges of Kansas State University.

ment of the Markov model by separate prediction by sex reduced both mean squared error and mean absolute error. This result accords with expectations since some departments such as engineering and home economics tend to be predominately male or female, respectively.

Table 3 explains more fully the relationships implicit in the Markov model. The extreme left column contains the enrollment probabilities as determined from the matched records; note that agriculture and home economics students are more likely to enroll than students who intend to major in business. The remainder of Table 3 exhibits the transition matrix of probabilities for those who enrolled. Thus, of those who intended to major in agriculture, 86% did so whereas the other 14% switched to other areas. Note that the main diagonal elements dominate (are larger than) the other elements in that row. This corroborates the findings of Lutz (1968).

As discussed previously, we had planned to use discriminant analysis to improve enrollment prediction. However, this approach was not fruitful. Inspection of the data revealed that the separation between variable means was not large in relation to the standard deviations of the variables considered, and discrimination of these variables was therefore unlikely. Hence, this approach was not warranted. Table 4 reveals only small differences between enrollees and nonenrollees except for the college choice variable. Also, we continued to detect only small differences after completing separate analyses by department.

TABLE 3

Enrollment Probabilities and Transition Matrix[a] of Probabilities for Enrollees

Enrollment Probability as Determined by Match		Indicated Preference	Actual Enrollment Category									
			1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
1.	.33	Agriculture	.86	.00	.02	.01	.00	.01	.04	.04	.02	.00
2.	.24	Architecture	.05	.73	.05	.00	.00	.00	.12	.00	.05	.00
3.	.23	Traditional Liberal Arts	.05	.02	.43	.10	.04	.02	.25	.03	.03	.03
4.	.23	Education	.01	.01	.07	.57	.03	.02	.18	.05	.00	.06
5.	.26	Health-Related Fields	.16	.00	.05	.04	.61	.00	.10	.02	.00	.02
6.	.20	Other Preprofessional Fields	.02	.00	.20	.02	.02	.42	.18	.07	.02	.05
7.	.23	Undecided or General	.07	.04	.11	.07	.03	.01	.44	.07	.10	.06
8.	.19	Business	.02	.00	.10	.05	.00	.04	.21	.51	.03	.04
9.	.27	Engineering	.04	.15	.04	.01	.01	.02	.09	.04	.60	.00
10.	.41	Home Economics	.01	.01	.02	.03	.01	.00	.30	.01	.00	.61

[a]First obtain the proportion say, a_i, in each indicated preference category after allowing for probability of enrollment. Let p_{ij} denote the entry in the ith row and the jth column of the transition matrix. Then the expected proportion in category j will be given by the basic stochastic relation: $q_j = \sum_i a_i p_{ij}$.

Conclusions and Discussion

Four major hypotheses are implied by the results of this exploratory study at one institution:

1. The student characteristics explored in this study will not differentiate enrolled from non-enrolled students adequately enough to appreciably improve enrollment projection accuracy.
2. Although a majority of students major in the curricular areas they choose as juniors and seniors in high school, preliminary choice of major does not appear to be particularly useful in making departmental enrollment projections.
3. Different models do a better job for different curricular departments.
4. Simple and straightforward projection models would appear to be just as useful as complex and sophisticated models.

TABLE 4

Mean Differences and Standard Deviations for Enrollees vs. Nonenrollees

Variable	Absolute Value of Mean Difference	S.D.
1. High School GPA	0.17	0.7
2. ACT English	1.0	4.4
3. ACT Math	1.7	6.5
4. ACT Social Studies	1.0	5.9
5. ACT Natural Sciences	1.2	5.9
6. ACT Composite	1.2	4.7
7. College Choice Number (coded 1, 2, or 3)	0.7	0.8
8. Family Income	129	6,974
9. Distance from Institution (coded 1, 2, 3, or 4)	0.14	0.66

Concerning these hypotheses, certain cautions should be pointed out. First, the study is based on only one institution, a particular medium-sized state university with relatively stable enrollment patterns. In addition, a number of institutions will find such a model unimportant because most students do *not* enroll in a particular major until after the freshman year.

A second problem is that the present study investigated only a few variables. It is possible that the inclusion of other types of variables such as interest inventory scores, personality variables, motivational variables, etc., would improve prediction markedly. On the other hand, pessimism might be warranted if we consider the lack of success obtained through the years in the multitude of studies which have tried to predict college dropout. It should also be mentioned, however, that this lack of prediction success has not curtailed the investigation of dropout prediction.

Another problem with this study is that no attempt was made to adjust for exogenous variables that obtained at KSU. For example, it is possible that arbitrary enrollment limits existed for certain departments. Similarly, other departments may have been so popular that full enrollment was virtually guaranteed. Knowledge of such constraints would provide a basis for making adjustments to the prediction models, and it is assumed that any institutional application of these models would be adjusted appropriately for similarly identifiable variables. In addition, it is important to note that enrollment projections could be affected by unusual events, such as student riots, which might require subjective interpretation of the results obtained.

The present study has explored only a few of the many possible methods for forecasting freshman enrollment in curricular departments. One intriguing possibility which has not been explored is a ratio model more advanced than the one investigated in the present study. It seems probable that a student's image of the college, as well as his knowledge about himself and the world of work, is a determining factor in not only whether the student enrolls but also the department in which he majors. Experience with the College and University Environment Scales and other college environ-

mental measures indicates that student images of the college change drastically after a short period of college attendance. Therefore, if we can predict which students are most likely to enter their preliminary curricular choice, we should be able to improve departmental enrollment projection over the simple ratio method.

Research has shown that students with similar first and second vocational choices are more likely to maintain their choices than are students who give divergent first and second vocational choices (Holland & Lutz, 1967) and that students' changes in occupational choice tend to be orderly and predictable (Holland & Whitney, 1968). Furthermore, vocational classification systems (e.g., Roe's and Holland's) are organized according to similarity between occupations and groups of occupations; and Holland and associates have prepared the foundation for a possible "occupational distance" or "distance between majors" measure (Holland, Whitney, Cole, & Richards, 1969).

ACT collects first and second choice, in addition to curricular choice, with its Student Profile Section. A college not requiring the ACT Assessment could easily collect such information on its application blank. By exploring curricular and major choice stability and change patterns, it may be possible for a college to adjust its ratio-derived projections. An additional desirable adjustment might be according to college choice number, using the method suggested by Hoyt and Munday (1968, pp. 119-122) for total institution enrollment projection.

In conclusion, it does seem that it is desirable to develop models for freshman enrollment projection. Such models could be especially important for "open door" institutions or for institutions where enrollment in a curricular department takes place at an early stage. Although not explored in this paper, the Markov model is uniquely suited to handle student flow from department to department and, as a consequence, could be conveniently adapted to the projection of upperclass enrollment. Combining this projection with the projection of freshman enrollment would make it possible for institutions to develop departmental total enrollment projections, thereby providing useful planning information for the allocation of staff, equipment, and facilities.

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